Experiment and simulation of gettering: Methods of removing iron from silicon wafers in solar cells

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1. Introduction

Multicrystalline silicon (mc-Si) accounts for about 50% of the world silicon photovoltaic modules production in 2009. Compared to mono-crystalline silicon, mc-Si requires less energy to produce and are thus cheaper. However, mc-Si are of a lower quality in comparison, partly due to the high amount of metal impurities such as iron in mc-Si. One way to improve the quality is through the process of gettering, where the Fe impurities are removed from the body of the wafer and trapped near the surface.

There have been various studies on the different methods of gettering. The 3 main gettering methods are:

1. Boron diffusion gettering (BDG)
2. Phosphorus diffusion gettering (PDG)
3. Aluminium annealing gettering (AAG)

However, most studies were focused on only one of the 3 gettering methods. Our project aims to compare all 3 different methods of gettering directly. In particular, the amount of Fe removed is compared using both experiment measurements and model simulations.

2. Experiment Methods

Since gettering is most useful for mc-Si, the experiment would be most relevant if mc-Si are used. However, mc-Si also contains a lot of other metal impurities such as Ni, Cu, and Cr, and dislocations and grain boundaries that may cloud the results. Furthermore, the initial distribution of Fe within mc-Si is not uniform even without any processing and may contribute to noise in the results.

Thus, low contamination mono-crystalline with little defects are used instead, and ion implantation of Fe is used to control the amount of Fe introduced to the samples. A range of temperature and doping concentration was used for the gettering conditions, while keeping other processes the same.

3. Model Simulations

The simulation solves the diffusions of B, P and Fe numerically, after dividing the wafer into many nodes and splitting the gettering time into small time steps.

At the start of each time step, the simulation will go through 3 steps:

1. Simulate the diffusion of B or P from the front surface.
2. Calculate the Fe solubility as a function of the concentration of B or P, to determine the segregation coefficient.
3. Simulate the diffusion of Fe towards regions of higher solubility.

4. Results and Discussion

Both measurement and simulation results agree well overall. BDG is found to be not effective at temperature above 850°C whereas PDG is effective over the range of temperature and doping level considered. AAG is very effective and has reached the detection limit of the measurement technique.

Adding a 1hr low temperature annealing (“tail”) after the standard boron or phosphorus diffusion can clearly improve the gettering effectiveness, because the segregation coefficient is improved at lower temperature.

5. Conclusion

The agreement between the measured and simulation results is well for the mono-crystalline silicon used. However, further quantitative understanding of the properties of various other impurities, and other precipitated forms of iron within the mc-Si are required for accurate simulation of gettering in mc-Si.